SOUTH CAROLINA IRRIGATION GUIDE

CHAPTER 8. IRRIGATION ENERGY USE

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CHAPTER 8. IRRIGATION ENERGY USE

GENERAL

With the high costs of energy, it is important that the irrigator examine every aspect of the irrigation system and seek ways to optimize energy use. It is possible to combine energy conservation techniques and good irrigation management practices to conserve both water and energy.

PUMPING PLANT EFFICIENCY

The pumping plant should be designed to deliver the water as economically as possible and is one area of the irrigation system where needed improvements in operating efficiency can be made relatively easy. Proper repair of a formerly efficient component, or proper selection of a replacement for an inefficient component, can bring efficiency up to the desired level.

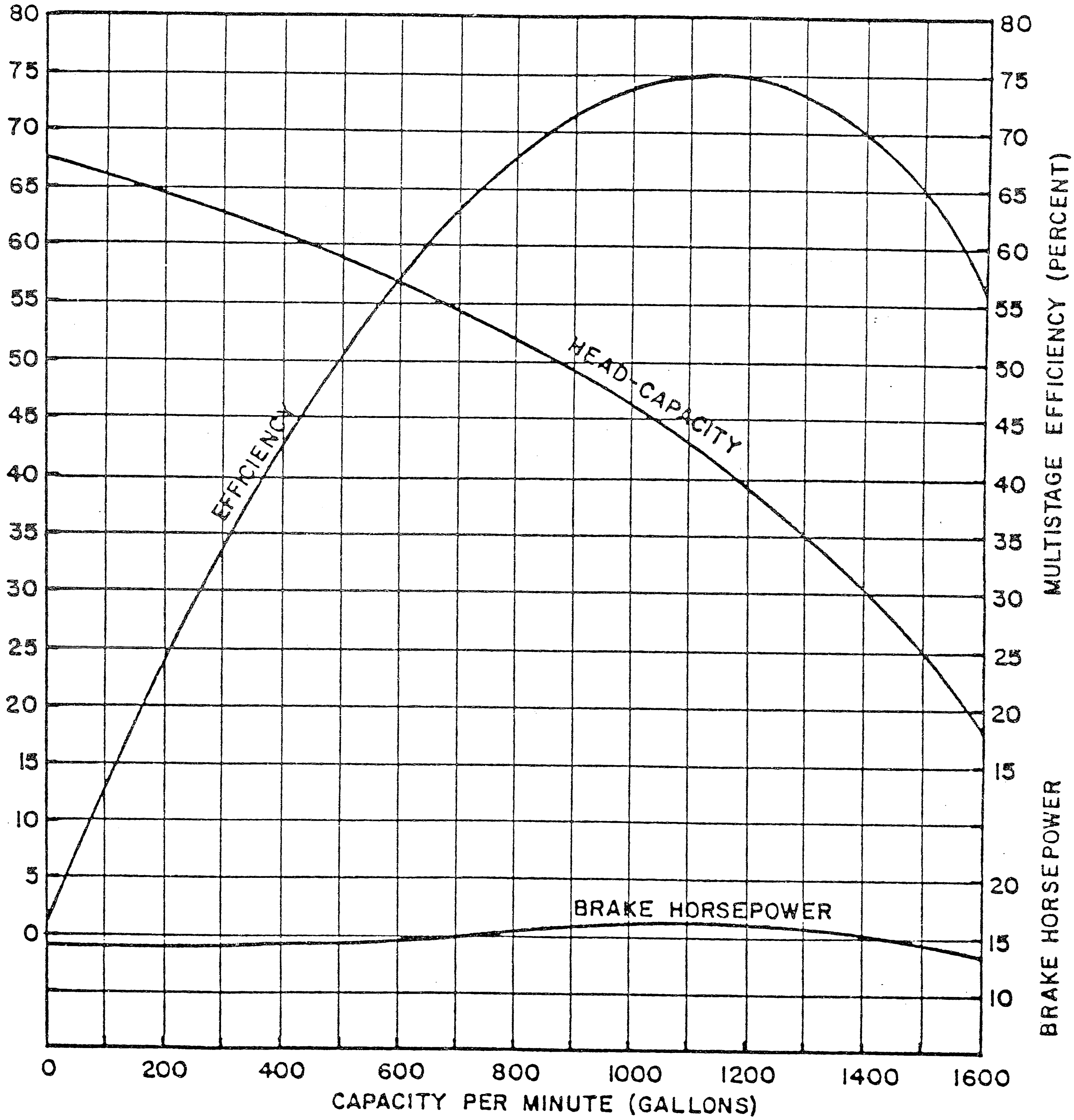
A pumping plant consists of three components - a pump, a power unit and a drive assembly. Drive assemblies will be discussed first. Direct drive assemblies - hollow-shaft motors, flexible couplings and tabular drive shafts - are 100 percent efficient in transmitting power. Nothing can be done to improve their power transmission efficiency. Belt drives are not 100 percent efficient. Pulley diameter, distance between pulley centers and belt tension, all affect belt life and power transmission efficiency. Properly designed, installed and maintained V-belt drives are capable of 95-97 percent efficiency while flat belt drives are capable of transmitting 80-90 percent of the power from the drive to the driven unit. Ninety (90) degree gear drives are 95 percent efficient.

Pump assemblies is one area where proper design and selection can really pay. One factor must be kept in mind. Each particular model/size of pump has its own operating characteristics. See Figure 8-1 showing a typical operating curve. The operating efficiency of a pump depends upon the combination of gallons per minute, discharge pressure and pump speed. A properly selected pump will have a high operating efficiency while delivering the desired combination of gpm and pressure. The most efficient combination of discharge and pressure varies with changes in pump speed. Changes in either pumping lift, discharge pressure or well yield also affect pumping efficiency.

The power unit is easier to maintain in top efficiency than the pump since it is readily visible and available to repair. Electric motors, especially three-phase units, are inherently quite efficient in converting electrical energy into mechanical motion. Internal combustion engines vary considerably in their ability to convert petroleum fuel into mechanical motion. Proper maintenance does much toward keeping the engine operating efficiently. Many irrigation engines have been selected on the basis of low initial cost. This has frequently resulted in a smaller engine being operated at its upper limits of revolutions per minute which not only shortens engine life but

Figure 8-1

PERFORMANCE CURVES OF A DEEP-WELL TURBINE OF THE MIXED-FLOW TYPE, SPEED 1,750 r.p.m.



$$\text{WATER HORSEPOWER} = \frac{Q\,(\text{gpm}) \cdot H\,(\text{ft})}{3960}$$

$$\text{BRAKE HORSEPOWER} = \frac{Q\,(\text{gpm}) \cdot H\,(\text{ft})}{3960 \cdot \text{efficiency}}$$

$$\text{PUMP EFFICIENCY} = \frac{\text{Output (Water) Horsepower}}{\text{Input (Brake) Horsepower}} \times 100\%$$

frequently increases the amount of fuel consumed per horsepower-hour of output. Manufacturers provide performance data on their engines which includes a curve showing the "amount of fuel per horsepower-hour" output by the engine at various speeds. See Figure 8-2 showing typical performance curves. Considering fuel consumption per horsepower-hour as well as initial price can be profitable.

PUMPING PLANT ENERGY REQUIREMENTS

There are three factors that determine the power and energy requirements of an irrigation pumping plant. They are:

1. The quantity of water being pumped expressed as gallons per minute (gpm).

2. The total dynamic head (TDH) expressed in feet.

3. The efficiency of the pump expressed as a decimal.

The useful work done by a pump or the water horsepower (whp) required is expressed by the formula:

$$\text{whp} = \frac{\text{gpm} \times \text{TDH}}{3960}$$

The water horsepower represents the power that would be required to operate the pump if the pump and drive were 100-percent efficient.

The brake horsepower (bhp) required to operate a pump is determined by the formula:

$$\text{bhp} = \frac{\text{whp}}{\text{pump efficiency} \times \text{drive efficiency}}$$

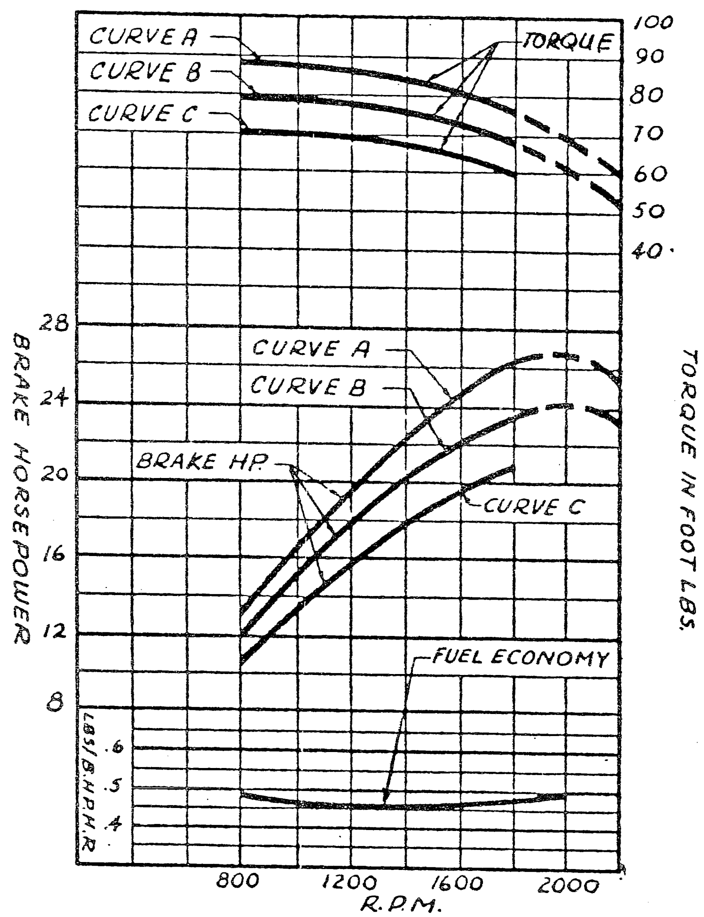
The horsepower requirement of the power unit is expressed by the following formula:

$$\text{Size of engine or motor} = \frac{\text{bhp}}{\text{efficiency of power unit}}$$

Inefficient irrigation pumping systems waste fuel and increase the cost per unit of water delivered. As fuel and electrical power costs increase, the cost of operating an inefficient pump increases even more.

Efficiency of a pumping system is defined as a ratio of the work being done by the system to the power or energy being supplied to it. Pump efficiency can be expressed as:

$$\frac{\text{output}}{\text{input}} = \frac{\text{whp}}{\text{bhp}}$$



Performance Curve of "166" Diesel Unit.

Curve A: Maximum performance.
Curve B: Maximum permissible for intermittent service.
Curve C: Maximum permissible for continuous service.

Equipment included: 4-blade fan, oil-bath air cleaner, muffler and generator.

Figure 8-2. Typical Engine Performance Curve

ENERGY FACTS

Table 8-1 presents performance standards for both power units and pumping plants. Power unit performance standards are given in terms of power produced (in horsepower-hours, hp-hr) per unit of fuel consumed (in gallons, gal or kilowatt-hours, kwh). These figures represent the efficiency of a typical power unit in converting fuel or electrical power to mechanical. Note the efficiency of a power unit (pumping plant) in this situation is a percent of the standard rather than a ratio of energy in (fuel) to energy out (whp). Pumping plant performance standards are given in water horsepower-hours (whp-hr) per gal or kwh. They include allowances for normal pump efficiencies, and friction losses in the discharge column and discharge head, but do not include drive assembly losses. Pumping system performance standards are expressed in terms of units of fuel consumed because they can be easily measured, whereas mechanical power input to a pump can be measured only with specialized instrumentation.

Table 8-1

Nebraska Performance Standards for Irrigation Pumping Plants

Fuel	Power Unit Performance Standards	Pumping Plant* Performance Standards
Diesel	14.58 hp-hr/gal	10.94 whp-hr/gal
Gasoline	11.30 hp-hr/gal	8.48 whp-hr/gal
Propane (LP-gas)	9.20 hp-hr/gal	6.89 whp-hr/gal
Natural Gas	88.93 hp-hr/1000 cu ft	66.70 whp-hr/1000 cu ft
Electricity	1.18 hp-hr/kwh	0.885 whp-hr/kwh

*Based on 75% pump efficiency. Figures do not include drive assembly losses.

From Table 8-1, it is readily seen that diesel fuel is the most efficient of the liquid fuels. However, the initial cost of a diesel power unit is usually considerably greater than that of other internal combustion engines.

PUMPING PLANT PERFORMANCE

A pumping performance test requires that the physical properties that determine pumping plant efficiency be measured. Pumping rate, pumping lift, pressure at the discharge outlet, and the amount of fuel consumed over a period of time must be measured while the pump is operating at its normal load. The engine and pump speed should also be measured to ensure that the manufacturer's recommendations are being followed.

CALCULATING PUMPING PLANT EFFICIENCY

An example set of field data is presented to illustrate the procedure for calculation of pumping plant efficiency:

Pump Discharge Rate, Q = 600 gpm
Pumping Lift, Le = 70 ft
Discharge Pressure, P = 60 psi
Pump Speed = 1750 rpm
Fuel Consumed (Diesel) = 4.0 gal
Pump Test Duration = 1.0 hr

1. Check Pump Speed:

   Pump should be measured with a portable tachometer to assure that the pump is being operated according to its specifications. The design pump operating speed should be stamped on a plate attached to the pump discharge head.

   In this example, the measured pump speed (1750 rpm) was found to be very nearly the required pump operating speed (1760 rpm). If it were not, speed must be adjusted before continuing.

2. Calculate Total Dynamic Head (TDH):

   TDH = Pumping Lift (ft) + Discharge Pressure (ft)
   TDH = 70 ft + (60 psi x 2.31 ft/psi)
   TDH = 70 ft + 139 ft = 209 ft

3. Calculate Water (Output) Horsepower, whp:

$$\text{whp} = \frac{Q \times H}{3960}$$

$$\text{whp} = \frac{600 \text{ gpm} \times 209 \text{ ft}}{3960}$$

$$\text{whp} = 31.7 \text{ hp}$$

4. Calculate Pumping Plant Performance:

$$\text{Performance (whp - hr/gal)} = \frac{\text{whp} \times \text{Test Duration (hr)}}{\text{Fuel Consumed (gal)}}$$

$$\text{Performance} = \frac{31.7 \text{ hp} \times 1.0 \text{ hr}}{4.0 \text{ gal}}$$

$$\text{Performance} = 7.9 \text{ whp - hr/gal}$$

5. Calculate Pumping Plant Efficiency, Eff

$$\text{Eff} = \frac{\text{Pumping Plant Performance}}{\text{Performance Standard}} \times 100\%$$

$$\text{Eff} = \frac{7.9 \text{ whp - hr/gal}}{10.94 \text{ whp - hr/gal}} \times 100\%$$

$$\text{Eff} = 72.2\%$$

6. Calculate Fuel Wasted per Hour:

Fuel Wasted/Hour = Current Fuel Consumption Rate x (1-Eff)

Fuel Wasted/Hour = 4.0 gal/hr x (1-0.722)

Fuel Wasted/Hour = 1.1 gal/hr

In this example, the actual pumping plant performance of 7.9 whp-hr/gal is only 72.2 percent of the performance standard for diesel powered pumping plants. For the size of unit described, 1.1 gal/hr of diesel fuel is wasted because the pumping plant is not operating efficiently in its current condition. Whether or not this loss in efficiency is significant enough to justify having the pumping unit repaired depends upon the expected repair cost and the number of hours of pump operation per year. In general, if the repair cost can be regained by savings in operating costs over a 2-3 year period of time, then it will be economically feasible to have the repairs made. The actual repayment time can only be calculated using a detailed economic analysis including the expected efficiency increases, fuel cost, and the repair costs amortized over the period of time.

CAUSES FOR SUBSTANDARD PUMP PERFORMANCE

Substandard performance in the pump can be caused by several factors. The pump could be mismatched for present conditions. The pump may not have been properly selected or the operarting conditions may have changed. The water table could have dropped or a new pipeline could have changed the pumping head requirement. The power source may not be operating at the specified speed (rpm) for maximum efficiency.

The impellers could be out of adjustment. Qualified repairment can adjust the impeller clearance with the bowl for the greatest efficiency. If the impeller is badly worn or corroded, adjustment will not help. Cavitation occurs in pumps that attempt to operate at flow rates greater than the well can supply. This pits the impellers and ruins them.

The engine may be loaded improperly. An internal combustion engine should be operated at its continuous horsepower rating at its design speed. Electric motors can be run continuously at 100 percent of their nameplate rating. Do not exceed the continuous bhp rating with a continuous load. Overloading an internal combustion engine can seriously shorten engine life as well as increase fuel costs.

The engine may need a tuneup. The ignition, timing, and carburetion should be adjusted on spark ignited engines. Diesel engines require fuel injection timing. Adjustments should be made by a qualified specialist to ensure maximum efficiency under the operating conditions. Electric motors excessively worn should be replaced. Compression tests can be run to check for the need to overhaul an internal combustion engine.

Poorly designed pumping systems would result in low efficiency ratings. This could be caused by such factors as an undersized suction pipe, restrictions in the intake strainer, or improperly sized discharge column. Misalignment of the drive shaft also decreases efficiency. Excessive wear is a sign of this.

ENERGY COSTS

Table 8-2 shows the cost per hour pumping for various fuels, fuel costs and horsepower loads. These will serve as valuable information in planning irrigation systems.

Figure 8-3 compares the cost of diesel, propane, and gasoline to the cost of electricity.

METHODS OF REDUCING ENERGY REQUIREMENTS

Proper selection, operation, maintenance and management of an irrigation system to fit the soil type and cropping system can save much energy. In the selection of an irrigation system, the system's energy costs should be considered as well as its initial costs. Sprinkler irrigation systems vary in the energy requirements. Single sprinkler volume guns are high energy users, permanent/solid-set systems are medium energy users and center pivot systems range from medium to low energy users. Subirrigation systems using furrows, ditches or pipes are relatively low energy users as well as trickle irrigation systems. Ways to save energy are discussed below.

INCREASING PUMPING PLANT EFFICIENCY

As was shown in the example on page 8-7, much energy can be saved by increasing the efficiency of the pumping plant. An irrigation pumping plant efficiency testing program was recently initiated in Georgia. Measured efficiencies have ranged from 12 percent to 119 percent and averaged 63 percent. This represents an average monetary loss of 37 cents per dollar of fuel cost and a potential energy savings of up to 9 million gallons of diesel fuel annually in Georgia if system efficiencies were increased to optimum levels.

REDUCING OPERATING PRESSURE

Lowering the nozzle pressure required can save energy. For example, suppose a comparison was to be made of purchasing two center pivot irrigation systems irrigating 100 acres. One system requires a pump operating pressure of 80 psi, the other 30 psi. Both operate at 800 gpm with a pump efficiency of 75 percent. The whp required for the systems are:

$$\text{80 psi system, whp} = \frac{(800\text{ gpm})\ (80\text{ psi} \times 2.31\text{ ft/psi})}{3960} = 37.3$$

Table 8-2. IRRIGATION POWER AND FUEL COST COMPARISON CHART

A - ELECTRICITY - Cost/hour of pumping (Based on 1.18 hp-hr/KWH*)

Pump Load HP	Rates per kilowatt-hour 4¢	5¢	6¢	7¢	8¢	9¢
10	$0.34	$0.42	$0.51	$0.59	$0.68	$0.76
20	0.68	0.85	1.02	1.19	1.36	1.53
30	1.02	1.27	1.53	1.78	2.03	2.29
40	1.36	1.69	2.03	2.37	2.71	3.05
50	1.69	2.12	2.54	2.97	3.39	3.81
75	2.54	3.18	3.81	4.45	5.08	5.72
100	3.39	4.24	5.08	5.93	6.78	7.63

B - DIESEL - Cost/hour of pumping (Based on 14.58 hp-hr/gal*)

Pump Load HP	Fuel cost per gallon $1.00	$1.10	$1.20	$1.30	$1.40	$1.50
10	$0.69	$0.75	$0.82	$0.89	$0.96	$1.03
20	1.37	1.51	1.65	1.78	1.92	2.06
30	2.06	2.26	2.47	2.67	2.88	3.09
40	2.74	3.02	3.29	3.57	3.84	4.12
50	3.43	3.77	4.12	4.46	4.80	5.14
75	5.14	5.66	6.17	6.69	7.20	7.72
100	6.86	7.54	8.23	8.92	9.60	10.29

C - GASOLINE - Cost/hour of pumping (Based on 11.30 hp-hr/gal*)

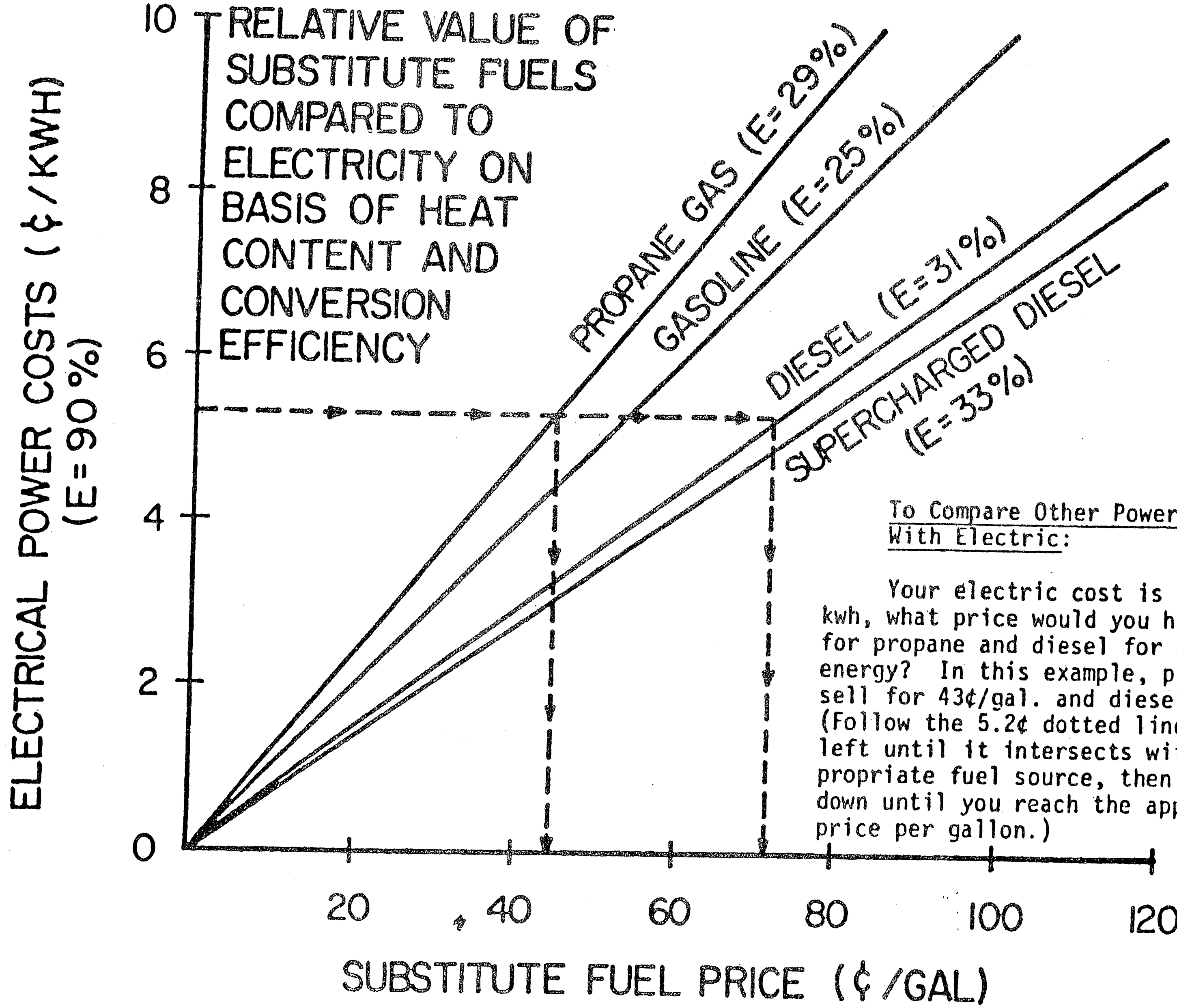
Pump Load HP	Fuel cost per gallon $1.00	$1.10	$1.20	$1.30	$1.40	$1.50
10	$0.88	$0.97	$1.06	$1.15	$1.24	$1.33
20	1.77	1.95	2.12	2.30	2.48	2.65
30	2.65	2.92	3.19	3.45	3.72	3.98
40	3.54	3.89	4.25	4.60	4.96	5.31
50	4.42	4.87	5.31	5.75	6.19	6.64
75	6.64	7.30	7.96	8.63	9.29	9.96
100	8.85	9.73	10.62	11.50	12.39	13.27

D - PROPANE - Cost/hour of pumping (Based on 9.2 hp-hr/gal*)

Pump Load HP	Fuel cost per gallon $0.80	$0.90	$1.00	$1.10	$1.20	$1.30
10	$0.87	$0.98	$1.09	$1.20	$1.30	$1.41
20	1.74	1.96	2.17	2.39	2.61	2.83
30	2.61	2.93	3.26	3.59	3.91	4.24
40	3.48	3.91	4.35	4.78	5.22	5.65
50	4.35	4.89	5.43	5.98	6.52	7.07
75	6.52	7.34	8.15	8.97	9.78	10.60
100	8.70	9.78	10.87	11.96	13.04	14.13

*Nebraska Standards for Engine Performance considered attainable in practice. Of 376 pumping plants tested in Nebraska 1956-62, only 33 or 8.8% exceeded the standard, 59% met or exceeded 75% of the standard. Efficiency of internal combustion engines can be expected to drop in normal use. Electric motor efficiency should change very little.

NOTE: All costs per hour are rounded to the nearest cent. Costs are for Fuel or power only, no lubrication, repairs, etc. Must divide by pump and drive efficiency to get actual cost/hour.



To Compare Other Power Costs With Electric:

Your electric cost is 5.2¢ per kwh, what price would you have to pay for propane and diesel for equivalent energy? In this example, propane must sell for 43¢/gal. and diesel for 70¢. (Follow the 5.2¢ dotted line on the left until it intersects with the appropriate fuel source, then proceed down until you reach the appropriate price per gallon.)

NOTE: This graph presents fuel costs only, and not associated changes such as electric power standby or demand costs.

Figure 8-3

30 psi system, whp = $\frac{(800 \text{ gpm}) (30 \text{ psi} \times 2.31 \text{ ft/psi})}{3960}$ = 14.0

The savings of using the 30 psi system over the 80 psi system would be 23.3 whp (37.3 whp - 14.0 whp).

From Table 8-1, for a diesel unit the fuel savings would be:

$$\frac{23.3 \text{ whp}}{10.94 \text{ whp-hr/gal}} = 2.1 \text{ gal/hr}$$

Using a diesel price of $1.15/gal, then the savings would be:

2.1 gal/hr x $1.15 gal = $2.42/hr

If the system is operated 500 hours per year, then the annual fuel savings would be:

500 hrs x $2.42/hr = <u>$1,210</u>
or
2.1 gal/hr x 500 hrs = <u>1050 gal of fuel</u>

Some farmers are converting from high pressure systems to low pressure systems. It should be understood that converting to low pressure systems will reduce pumping costs only if the pumping plant is designed for low pressure. Most pumps are set to deliver a given gpm at a given head to get the maximum efficiency of the pumping plant. When this head is reduced, the gpm will increase. This usually results in a lower efficiency for the pumping plant, with the consequent higher energy use for pumping an acre inch of water.

Converting high pressure center pivot to low pressure center pivot reduces the wetted diameter of the sprinklers on the order of $\pm$100 feet to 40 to 60 feet. So the same amount of water would be put on a strip about half as wide with low pressure center pivots. Therefore, the application rate of water is about twice as much in inches per hour. This can cause serious runoff on the heavier soils especially where there are sloping areas. This should be given consideration when deciding on converting center pivot systems from high pressure to low pressure.

SIZING OF IRRIGATION PIPELINE

The friction loss in a pipeline increases, approximately, in proportion to the square of the water velocity in the pipeline.

Water Velocity ft/sec	Square
1	1
2	4
3	9
4	16
5	25

Consider friction loss to be comparable to energy use. The higher the friction loss the more energy that is required to pump water through a pipeline.

Compare the three foot per second velocity to the four foot per second velocity in the table above. This compares three squared which equals nine to four squared which equals sixteen. Sixteen divided by nine equals 1.78. Friction loss at a velocity of four feet per second is approximately 1.78 times the friction loss at three feet per second.

It is considered advantageous to keep pipeline velocities between three and four per second considering initial cost of the material, installation costs and operating costs.

Obviously, on very short pipelines or irrigation systems using gravity flow it may not be advantageous to keep the velocities low because there would be very little savings in operational costs. In this case, five feet per second velocities are considered a maximum to prevent problems connected with surge, water hammer and air entrapment.

On very long pipelines, it may be advantageous to reduce the pipeline velocity to as little as two feet per second thus reducing energy use. Initial material and installation costs should be studied and compared to operating costs to determine the most economical pipe size to be installed. The biggest cost in installing larger pipes is the increased cost of material. Trenching, backfilling, and labor costs usually increase very little when a pipe diameter is increased one size. Velocities should not be dropped below two feet per second unless special studies are made of potential sediment problems.

Example of sizing a pipeline based on energy use and annual pipe cost.

Reference: Appendix C, Friction loss characteristics P.V.C. Class 125.

I.P.S. Plastic Pipe, SDR 32.5

Given: Q = 1000 gallons per minute

pipeline length = 3000 feet

operating time = 1000 hours per year

electricity cost = 5 cents per kw-hr/hr

diesel fuel cost = $1.10 per gallon

total dynamic head = 100 feet + friction loss in pipeline

Pipeline Friction Loss

Pipe Size (Dia)	Velocity (ft/sec)	Friction Loss psi/100 ft	Friction Loss ft head/100 ft	Friction Loss in 3000 feet
8 in	6.22	0.58	1.34	40 ft
10 in	4.00	0.20	0.46	14 ft
12 in	2.84	0.09	0.21	6 ft

It should be noted to begin with that the 8 inch diameter pipeline should not be used because of velocities exceeding 5 ft/sec. This could cause water hammer, surge, or air entrapment problems. The 8 inch size is being shown in the example to illustrate the extra cost associated with higher velocities.

Cost of Electricity

Pipe Size (Dia)	Total Head Loss	whp	whp-hr per kwh	kw-hr per hr	Cost/hr @$0.05/kwh	Cost per 1000 hrs
8 in	140	35	0.885	40	$2.00	$2000
10 in	114	29	0.885	33	1.65	1650
12 in	106	27	0.885	30	1.50	1500

Cost of Diesel

Pipe Size (Dia)	Total Head Loss	whp	whp-hr per gal	gal per hr	Cost/hr @$0.80/gal.	Cost per 1000 hrs
8 in	140	35	10.94	3.2	$2.56	$2560
10 in	114	29	10.94	2.7	2.16	2160
12 in	106	27	10.94	2.5	2.00	2000

The annual amortized pipe cost using the following conditions are:

Pipe Size (Dia.)	Initial Cost	Life (Yrs)	Interest Rate	Annual Amortized Cost
8 in	$11,640	25	12%	$1484.
10 in	$16,500	25	12%	$2104.
12 in	$22,050	25	12%	$2811.

The most economical pipe size would be the one that has the lowest total cost considering both the annual amortized cost and the energy cost as follows:

Pipe Size (Dia.)	Annual Amortized Cost	Annual Energy Cost	Total Cost
	Electric		
8	$1484.	$2000	$3484
10	2104.	1650	3754
12	2811.	1500	4311
	Diesel		
8	$1484	$2560	$4044
10	2104	2160	4264
12	2811	2000	4811

The most economical pipe would be the eight inch size with the ten inch being the next choice. Due to possible water hammer and surge problems with the eight inch size, the ten inch pipe would be the recommended size.

SCHEDULING WATER APPLICATIONS

Probably the one place where energy savings can be affected the quickest is to use management practices which obtain the optimum return on the investment. Many times, irrigation chores are done at the operator's convenience rather than when needed. Many pump irrigators could use less water without reducing yields by using more timely scheduling of water applications.

Knowing the consumptive use of the crop and soil moisture content can reduce the amount of water applied thereby reducing energy cost.

In the above example, if 1 acre-inch of water is saved through properly scheduling irrigation applications, the amount of fuel saved would be:

$$\text{fuel saved} = 100 \text{ acres} \times \frac{1 \text{ ac-in}}{\text{ac}} \times \frac{27{,}154 \text{ gal}}{\text{ac-in}} \times \frac{1 \text{ min}}{800 \text{ gal}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{2.1 \text{ gal}}{\text{hr}}$$

$$= 118.8 \text{ gal of diesel fuel}$$

INCREASING APPLICATION EFFICIENCY

Increasing the application efficiency of the irrigation system will directly save water and energy. This can be done by selecting a system of known high efficiency, designing and laying out the particular system to obtain the most efficiency application possible or irrigate at times when the efficiency would be greater. The example below will illustrate how increasing the application efficiency will save energy.

Assume the system previously discussed with 70 percent application efficiency and an 80 percent application efficiency. If the next irrigation requirement is 1 inch then the gross irrigation requirement for the two efficiencies are:

70 percent = 1.00 inch ÷ 0.70 = 1.43 inches gross application
80 percent = 1.00 inch ÷ 0.80 = 1.25 inches gross application

fuel used at 70% eff. of application

$$= 100 \text{ acres} \times \frac{1.43 \text{ ac-in}}{\text{ac}} \times \frac{27{,}154 \text{ gal}}{\text{ac-in}} \times \frac{1 \text{ min}}{800 \text{ gal}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{2.1 \text{ gal}}{\text{hr}}$$

$$= 169.9 \text{ gal}$$

fuel used at 80% eff. of application

$$= 100 \text{ acres} \times \frac{1.25 \text{ ac-in}}{\text{ac}} \times \frac{27{,}154 \text{ gal}}{\text{ac-in}} \times \frac{1 \text{ min}}{800 \text{ gal}} \times \frac{1 \text{ hr}}{60 \text{ min}} \times \frac{2.1 \text{ gal}}{\text{hr}}$$

$$= 148.5 \text{ gal}$$

The fuel saved per 1-inch net applications is 21.4 gal (169.9 gal - 148.5 gal). If six 1-inch net applications are required in one season, then 128.4 gallons of fuel could be saved.